XX. *On the formation of fat in the intestine of the tadpole, and on the use of the yelk in the formation of the embryo in the egg.* *By Sir* Everard Home, *Bart. V. P. R. S.*

Read May 23, 1816.

The tadpoles in England are so small, that no person has attempted to make an accurate investigation of the internal changes of structure that take place in them, between the time of the animal leaving the egg and becoming a frog.

The rana paradoxa of Surinam, in its tadpole state, is larger than in any other species of frog yet known, and so closely resembles fishes, that in that country it is sold as such in the market, for the use of the table, under the name of Jackie; and, as the frog produced from it, is in the first instance as large as a common frog in this country, it is highly probable, that it becomes an animal of considerable size. Mr. Ireland, a surgeon in the army, who resided several years at Surinam, and watched the tadpole through many of its changes, has brought home specimens in different stages of its metamorphosis. These he has kindly submitted to my examination, and has in the most liberal manner, deposited the specimens in the Museum of the Royal College of Surgeons in London, of which he is a member.

As Mr. Ireland had no opportunity of examining the tadpole, before the hind legs begin to make their appearance through the skin; with a view to render the series complete, I have since examined the progress of the changes, from the

ovum in the spawn of the English frog.* The jelly of which the ova are composed, I have upon a former occasion given an account of to the Society. The ova themselves differ from those of snakes and lacertæ in general, in having no yelks. When the tadpole is once formed, it appears to feed upon the jelly, which although not absolutely albumen, is a near approach to it.

In this stage, each ovum is pressed into the form of an hexagonal prism with flattened ends, so as to form the whole into one compact mass.

The tadpole, after it leaves the ovum, has on each side ten filaments projecting from the neck, for the purpose of aeration of the blood; such filaments must be considered as temporary gills.

The lacerta of this country, called the newt or eft, in its larva state, has the same projecting filaments, which drop off when the gills are formed; they are more complex in their structure, and only three in number, on each side. This circumstance shows, that the larva of an eft is a species of tadpole, and that the eft itself does not belong to the tribe of lizards, but is a nearer approach to that of frogs. In the tadpole, as soon as the abdomen begins to enlarge, these external filaments disappear. Twenty-four similar filaments are met with in the fœtus of the shark while contained in the egg, which drop off before the fœtus escapes from the shell.

The spawn of the English frog was collected on the 1st of April, 1816. On the 15th, the tadpole left the egg, but the filaments or external gills were not visible, only a deep notch

* The tadpoles having become frogs since this Paper was read, I have been enabled to complete the series.

on each side nearly separating the head from the body. On the 23d, the ten filaments on each side were distinct; on the 27th they disappeared. In June, the external orifice on the left side, for the water to pass off from the gills, was very distinct, but none was seen on the right. On July the 8th, the hind legs began to appear, but the toes were not separated. On the 14th of July, the hind legs were seen externally completely formed, and on opening the skin of the chest, the fore legs were equally so; but there was no external projection by which this could be known. The lungs were completely formed. On removing the intestine, there was no fat deposited on the loins. On the 16th, the contents of the intestine were voided in considerable quantity. On the 18th, the elbows of the fore legs projected under the external skin, and so much of the contents of the intestine had been voided as to give a taper form to the lower part of the body. On the 19th, the fore legs were completely disengaged and appeared externally; the mouth had become wide like that of a frog. The tail had a notch at that part where it afterwards separates; the intestine was reduced in diameter, and to the length of that of a frog; an appearance of oil was seen on the loins. On the 23d, the tail had dropped off, leaving the projecting root. The animal had left the water and remained among the grass. Behind the intestines upon the loins were several small membranous appendages in an empty state.

On the 28th, the root of the tail had wholly disappeared; the appendages had become more opaque.

The ova of the frog appear to be hatched at very different periods, since some of the tadpoles become complete frogs, before others have their hind legs protruded through the skin.

Upon examining the tadpole of the rana paradoxa, just

when the hind feet appear externally, I found the mouth very small, and nearly round, the teeth cuticular, the upper ones overlapping the under, the œsophagus, stomach, and intestine, forming one uniformly continued canal, which passed down to the lower part of the abdomen; it was bent upon itself, passed up again, and then made a great number of coils in a circular form; its coats were very firm, its capacity very small. There were three gills completely enclosed on each side, and a little way below the eye on the left side, a small round orifice, for the water, by which the gills are supplied, to pass out; but none on the right. When the tadpole is arrived at its full growth, and the hind legs are completely formed, which takes place, according to Mr. Ireland's observations, in 14 days after their first appearance, the cavity of the abdomen had become exceedingly enlarged, the intestine very capacious, its coats almost as thin as cobweb: it was completely distended, through its whole extent, with a soft substance, which when burnt had the smell of hay. Behind the intestine, all along the posterior part of the abdomen, a large quantity of fat was met with of a yellow colour, enclosed in long, thin, transparent membranous bags; no part of this fat was met with in the prior stages of the tadpole's growth. The lungs were completely formed.

When the mouth of the tadpole has been changed into that of the frog, and the fore legs completely protruded, but the tail remaining entire, which happens 21 days after the last mentioned change, the large coils of intestine were found contracted into a canal one fourth of its original length; the coats had become as firm as those of an artery, the external surface was corrugated and the canal empty. The stomach had become a distinct cavity, and there was a contraction, where it

terminates in the intestine. All these parts were embedded in fat, which filled every part of the abdomen, not occupied by the liver, which had acquired a large size. The lungs were filled with air, and the gills had entirely disappeared.

When the tail has dropped off, leaving the projecting root, which takes place in seven days more, the only internal change met with, was, that no fat whatever was found in the cavity of the abdomen.

The great length of the intestine which has been described, has nothing analogous to it in the caterpillar, and is probably confined to the frog tribe.

The egg of a frog bears no proportion in size, to those of the other animals of the same class, and differs from them in having no yelk, therefore, although it contains sufficient materials for the formation of the tadpole, something is still wanting, before it can be metamorphosed into a frog; and in the tadpole state, a store of fat is laid up, beyond what is required for its own immediate support and future growth, to furnish the necessary means of supplying the different structures in the frog, not already existing in the tadpole; and this fat appears to be formed in the intestine.

The length of intestine in the tadpole, when its relative proportion to the size of the animal is considered, exceeds every thing of the kind that is met with in other animals.

In the tadpole of the Surinam frog, the intestine after it has acquired its full size, does not remain of this enormous length, beyond the period of its metamorphosis into the frog taking place; and what is deserving of particular attention, the fat is deposited, when the intestine has acquired its full size, and no sooner is the intestine reduced in length, than not only no

more fat is deposited, but all that was previously formed is found to have been consumed, in producing the metamorphosis into the frog: which leads me to conclude, that such a deposit of fat is necessary to the metamorphosis of a tadpole into a frog, and that such unusual length of intestine, is required to admit of so large a quantity of fat being formed in so short a time, and, therefore, that the intestine is the laboratory in which the fat is formed.

To ascertain, whether the necessity of such a supply of fat is occasioned by the soft parts of the tadpole not being convertible into bones, and other parts of the frog, which did not exist in the tadpole, or, simply, from a deficiency of materials, I have had the assistance of my friend and fellow labourer in animal chemistry, Mr. HATCHETT, who some years ago ascertained, that the yelk of an egg is essentially composed of concrete oil, combined with a small proportion of albumen, and he has made out the following important facts. "That the spawn of the frog, has no yelk, and contains no oil whatever; he also corroborates Mr. BRANDE's statement, that it consists of a substance intermediate between albumen and gelatine, inclining principally to the former. That the ova of the shell snail, both of those that have a shell, and those that have only a strong membranous covering, have no yelks, and consist of albumen, since they coagulate in proof spirit of wine, and, when so coagulated, and examined some time afterwards, appear not to contain any oil. That the ova of the lobster have no yelk, and contain no oil.

But he remarks, that the spawn of the lobster, when recent, is filled with albumen mingled with a substance of a dark olive colour, and whilst the former as usual is coagulated by heat,

the latter becomes of a vivid red; this, Mr. HATCHETT observes, is the colouring matter of the shell, which three or four years ago, Mr. BRANDE found to become red by the application of acids without heat; for dilute sulphuric, nitric, muriatic, and the strong acetic acids immediately produce the same effect on the colouring matter of the spawn, but this is not the case when a weak acid, such as common distilled vinegar, is employed.

When this bright red colour has been produced by the above acids, it appears to be permanent, excepting when nitric acid has been used, for then the red colour changes to yellow, which by the affusion of ammonia becomes orange colour, as is usual with animal substances so treated.

Dilute nitric acid in which it had been digested, afforded slight traces of a phosphate, which was not phosphate of lime.

As the red colour is produced by acids as well as by heat, there was some reason to expect that it would have been destroyed, or at least that its intensity would have been diminished by a great excess of the alkalies, but not the smallest effect was produced by any of these, and indeed so far from it, that the recent spawn when put into a solution of caustic potash, became in a few seconds changed to as bright a red as when the mineral acids had been employed.

The red colour is also produced by the effects of air, light, and the evaporation of moisture, for paper or linen which have been stained with the olive coloured substance, become red in the course of a few minutes, so that in this respect it somewhat resembles the secretion obtained from the buccinum lapillus, or purple whelk. The purple colour of this last does not, however, suffer any change, whilst the colouring

matter of the lobster in the course of some days becomes of an ochraceous colour. In this state it seems to be permanent, for it was retained by linen which had been marked with it, after repeated boiling in water and washing with soap.

From these cursory experiments, Mr. HATCHETT observes, that this animal colouring substance is apparently of a peculiar nature, and that it is the same in the common cray fish and the prawn, as well as in the sea cray fish and the crab, but in the two last, it has already assumed its red colour.

That the ova of the salmon and pike have no yelk, and consist principally of albumen, as they coagulate by heat, but contain also a small portion of oil, which perhaps is a substitute for yelk.

That the ova of the cartilaginous fishes, as well as those of the lizard and snake, have a regularly formed yelk, like that of the hen, composed of the same ingredients; but in both the viviparous and oviparous sharks there is no perfectly formed albumen, but in its place a gelatinous substance, which Mr. BRANDE ascertained to be intermediate between gelatin and albumen, similar to what is met with in the spawn of the frog.

In addition to that which has been above stated, Mr. HATCHETT has communicated to me the following observations.

"The yelk of the eggs of birds is principally and essentially composed of a butyraceous oil, combined with a small proportion of albumen, the average of which in the yelk of the common fowl amounts to about one fifth. Yelk, when triturated and diluted with water, forms (as is well known) an emulsion, and yelk may be regarded as an emulsion in a high state of concentration.

In milk, the caseous part, or curd, corresponds to the albuminous part of yelk, as the butter in milk does to the other part or oil of the yelk. The principal difference, therefore, between milk and yelk is, that the former is in a dilute, and the latter in a concentrated state. Hence, Mr. HATCHETT observes, it appears that many of the oviparous animals during the period of incubation, are nourished by a pabulum similar in quality to that by which young viviparous animals are supported, whilst the great degree of concentration of this pabulum in the first case is essentially necessary, in order that the quantity of nutritious matter which is required during incubation, and which is included with the animal within the egg, should be condensed into the smallest possible bulk.

Young viviparous animals are at first incapable of supporting themselves by those substances which are afterwards to become their food, and they are therefore nourished for a certain period of time by the milk of their mothers; but young oviparous animals, such as the chicken, partridge, and birds in general, come forth from the shells complete in their bodily faculties, and immediately partake of the food to which the parent birds are accustomed, so that it seems they are prepared for this, and are nourished during incubation, by a substance similar in its nature to that by which young viviparous animals are supported, or suckled, during a certain time after their birth, and that the process corresponding to that of suckling, is, with regard to birds, performed and completed in the course of incubation.

The experiments which Mr. HATCHETT has made upon the ova of these different tribes of animals, lead to the conclusion, that in all ova, the embryos of which have bones, there is a

certain portion of oil, and in those ova whose embryos consist entirely of soft parts, there is none.

This conclusion is much strengthened by the peculiarity, which it has been my object in this paper to point out, of the tadpole laying up a magazine of fat before the metamorphosis into a frog takes place; it is, therefore, rendered probable, that a certain portion of oil is necessary for the formation of bone, and that the proportion in different ova corresponds with the greater or less degree of hardness of the bones of the fœtus.